Flexible Ferrule Device for Connection of Optical Fiber and Use Thereof

BACKGROUND OF THE INVENTION

The present invention is directed to a connector assembly for connecting optical fibers for use in optical communication systems, and particularly to a flexible ferrule device for connecting optical fibers for such use. The present invention further relates to a method of connecting optical fiber using such device and to a tool for use thereof.

The invention relates to an optical fiber connection device that allows for the end-to-end alignment of two optical fibers in a way such as to permit a light signal to pass from one fiber to the other fiber with minimal attenuation and reflection losses. This device also makes it possible to reduce any air layer between the ends of the two fibers in contact by maintaining pressure on their ends.

Ferrules and related technology are known in fiber optic connection. The art is replete with examples, including U.S. Patent N^{os} 6,579,615 B2; 6,533,469 B1; 6,416,236 B1; 6,357,933; and U.S. Patent Application Publication N° U.S. 2002/0037140. A ferrule for use as a connector in an assembly with optical fibers requires high dimensional accuracy and precision, yet in an extremely small-diameter conduit for positioning and holding optical fiber. Present or proposed ferrule connectors for optical fibers, such as U.S. Patent Number 6,357,933 to Lucent Technologies Inc. may not be amenable to ease of manufacture or assembly with optical fiber by the technical personnel carrying out the operation. Thus in spite of the known application of ferrules in optical fiber connection, there is a continuing need for improvement in the technology of the design and use of ferrules for this purpose. For example, relating to aspects of attenuation and return loss, the establishing of as perfect as possible fiber-to-fiber contact between end portion of optical fibers and the prevention of face dust accumulation between the fiber faces. There

is also a need to improve the ease of use of ferrules in an assembly for connection of optical fibers in an optical communication system, by the person carrying out the operation.

In the field of photonics, optical fibers are used for the transmission of optical signals as well as for the linking of optical switches, waveguide grating devices, optical amplifiers, module and the like. Optical transmission systems relying on photonics have been taking on greater importance as optical signals are capable of carrying a far larger quantity of information as compared to typical copper wire communication systems. For example, with the technology of Dense Wavelength Division Multiplexing (DWDM) and Demultiplexing it is possible to transmit multiple wavelengths in a single fiber, providing data capacities of 40 Gigabits per second and greater.

Optical networks which require DWDM equipment and other such devices demand multiple amounts of splicers and connectors. Splicing and connecting play a significant role in network cost and performance. Although mechanical splicing of optical fibers may be sufficient where there is no requirement for frequent connection and disconnection, current technologies for connectors or for splicing are still time consuming and expensive, since they are difficult to miniaturize and to manipulate. As well, there will be circumstances where connectors will be used in applications where flexibility for routing or reconfiguration is necessary or for connection of an end use device, such a computer or other electronic device to a fiber or to other such devices. Current technologies for connectors or for splicing are still time consuming and expensive, since they are difficult to miniature and to manipulate.

As poor connection between the ends of two optical fibers will lead to signal distortion and loss of strength, a number of approaches have been proposed for proper optical fiber connections which will provide a good signal conduction. One such approach

is set out in our U.S. Patent N° 60/358,392 titled "A Connector for Optic Fibers" PCT/CA03/01195. This application is incorporated herein by reference in its entirety.

In our aforesaid application, we propose a connector for connecting the ends of two optical fibers by abutment, wherein the connector is divided into a plurality of fingers that extend longitudinally at each end and a fiber conduit extending from the first end to the second end. Such a connector is manufactured from shape memory material, such as polymer ceramic or a metal alloy, with low elastic modulus. In general, such materials when deformed from a rest condition by any suitable means, such as by mechanical deformation or temperature increase, will then be biased to return to a rest condition when the cause of deformation is removed.

Use of such an optical fiber connector as described above is however not totally satisfactory as during the step of cooling or release of stress the connector to allow it to return to its rest condition, there may be a tendency for the connector to push the ends of the optical fibers apart slightly. This makes it necessary during the operation of connecting optical fiber ends to include an additional step of restraining the optical fibers in a fixed position during the step where the connector returns to its original size, to prevent the optic fibers from being moved apart on the cooling of the connector. Accordingly, some form of fixed clamping is required, of the sheath that typically covers and protects an optical fiber or bundle of such fibers to prevent axial movement of the optic fibers being connected. Such step is cumbersome to the easy and quick connection of optical fibers using an aforesaid connector, requiring a certain degree of operational skill on the part of the technician carrying out the operation.

Accordingly, although a SMA connector as described in our U.S. Application N° 60/358,392 provides an improved means for connecting optical fibers, this still requires the use of certain operational skill by a technician carrying out the operation. As well, there is a need for improvement, such as in attenuation and return loss, fiber-to-fiber

contact, dirt accumulation and the like, in relation to optical fiber connection with ferrules, despite the common use of such technology in the field of optical signal transmission. Thus, there is a continuing need for an optical fiber connector assembly that is simple and quick to install and use and to maintain a good signal conduction between optical fibers, as well for a connection to be made and provided at a near end use device.

For purposes of the present application, with respect to shape memory material (SMM), reference may be made to AFNOR Standard "Alliages à mémoire de dorme – Vocabulaire et Mesures" A 51080-1990, herein incorporated entirely by reference.

Materials, which are suitable for the present invention, will illustrate a very low Young's modulus (elastic modulus) and /or pseudo elastic effect. Pseudo elastic effect is encountered in SMM. Concerning the shape memory effect, when the material is below a temperature (M_F), which is a property dependent on the particular SMM, it is possible to strain (deform) the material from about some tenths of a percent to more than about eight percent, depending on the particular SMM used. When the SMM is heated above a second temperature (A_F), which is also dependent on the particular SMM as well as the applied stress, the SMM will tend to recover its assigned shape. If unstressed, the SMM will tend toward total recovery of its original shape. If a stress is maintained, the SMM will tend to particularly recover its original shape. Concerning the pseudo elastic effect, when the SMM is at a temperature greater than its (A_F), it may be strained at particularly higher rates, that is exhibiting non-used elasticity, arising from the shape MEMORY properties. Initially, in the SMM when stressed the strain will increase linearly, as in a used elastic material. However, at an amount of stress, which is dependent on the particular SMM and temperature, the ratio of strain to stress is no longer linear, strain increases at a higher rate as stress is increasing at a lower rate. At a particular higher level of stress, the increase in strain will tend to become smaller. This non-linear effect exhibited by SMM a

temperature above (A_F) may manifest itself as a hysteresis like effect, wherein on the release or reduction of stress the deduction in strain will follow a different curve from the one manifest as stress was increased, in the manner of a hysteresis like loop.

An example of such an above material would be a shape memory alloy (SMA). Examples concerning activation of the shape memory element in a SMA include *D.E. Muntges et al.,* "Proceedings of SPIE," Volume 4327 (2001), pages 193-200 and *Byong-Ho Park et al.*, "Proceedings of SPIE," Volume 4327 (2001), pages 79-87. Miniaturized components of SMA may be manufactured by laser radiation processing. See for example *H. Hafer Kamp et al.*, "Laser Zentrum Hannover e.v.," Hannover, Germany [publication]. All of the above references are incorporated herein by reference.

The connector may, for example, be made from a polymeric material, such as isostatic polybutene, shape ceramics such as zirconium with some additions of Cerium Beryllium or Molybdenum, copper alloys including binary and ternary alloys, such as Copper – Aluminum alloys, Copper – Zinc alloys, Copper – Aluminum – Beryllium alloys, Copper – Aluminum – Zinc alloys and Copper – Aluminum – Nickel alloys, Nickel alloys such as Nickel – Titanium alloys and Nickel – Titanium – Cobalt alloys, Iron alloys such as Iron – manganese alloys, Iron – Manganese – Silicon alloys, Iron – Chromium – Manganese alloys and Iron – Chromium – Silicon alloys, Aluminum alloys, and high elasticity composites which may optionally have metallic or polymeric reinforcement.

To connect the ends of two optical fibers using our ferrule connector, the connector must be first deformed in any suitable way, such as by the application of a compressive force along its longitudinal axis. An optical gel may also be applied, which would be substantially of the same index of refraction as the optical fibers to assure uniform optical properties across the connection between the fibers.

Once the optical fibers ends are fully inserted into the connector, and the respective ends abut, the force applied on the connector may then be released and the

connector allowed to return to an initial shape. On released of the force on the connector, the connector will then tend to exert a controlled compressive force on the optical fibers, sufficiently strong enough to retain the optic fibers in an abutment position but small enough not to damage the optical fibers by compression.

SMA technology is particularly suited to optical fiber connection, as it offers mechanical retention of fiber and can create an abatement between and faces of fibers.

SUMMARY OF THE INVENTION

The device for connecting optical fiber comprises a ferrule and end caps with wire centers of which the extremities are located at the centerer of the ferrule; said ferrule comprising a bore that traverses the central axis of the ferrule, a middle portion or centerer, connecting clamp means at the ends of the ferrule, linked together by the centerer; the ferrule being made of any material that has the property of shape memory, and deformation equipment allowing for its implementation.

Unless otherwise indicated herein, in the present document "device" refers to the device that connects optical fibers.

BRIEF DESCRIPTION OF THE FIGURES

Reference will now be made by way of example to the accompanied figures, showing articles made according to the preferred embodiments of the present invention.

Figure 1 is a perspective view of the ferrule in accordance with the present invention;

Figure 2 is a perspective view of the tool showing the opening of the "centerer" on the ferrule.

Figure 3 illustrates the placement of the first fiber.

Figure 4 illustrates the placement of the second fiber.

Figure 5 illustrates the removal of the tool.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described more fully hereafter with reference to the accompanying drawings in which preferred embodiments are shown.

A. ***Device embodiment*:**

The device for connecting optical fibers comprises a ferrule and may be made from any suitable material such as either a polymer based material, metallic alloy or ceramic or any material that has a low Young's modulus such as polymeric materials or Cu_2Be elastic alloys or any material that has the property of pseudo elasticity for its implementation. The shape memory material may be any as described above, with desired properties. The shape memory material may be copper or iron alloy, or it can be a nickel/titanium alloy. The composition of the shape memory material may be more complex and include other elements in variable quantities.

The shape memory material is advantageously used in its austenitic phase for the realization of an optical-fiber connecting ferrule. In effect, in this phase, it has deformation capabilities, referred-to as pseudo-elastic, which are more important than the elastic-deformation capabilities of a metallic or ceramic alloy that does not have the properties of shape memory.

The ferrule is generally cylindrical and, before its first connection to optical fiber, it is characterized by the elements described in Figure 1, namely: **a bore** (1) that traverses the central axis of the ferrule, from one end to the other end; **a middle portion** (2), commonly referred to as "centerer", at a level wherein the diameter of the bore of the ferrule is slightly smaller than the diameter of the optical fibers that it is to connect. With respect to the present invention, this "centerer" has the function (a) to centre, the two optical fibers with just sufficient radial distortion allowed to ensure that the two fiber cores are face to face with the minimum of misalignment in order to obtain an optimal optical signal transmission;

(b) to firmly maintain each of the two optical fibers in place so they cannot separate from one another; (c) to maintain the two optical fibers in contact with each other with an axial strength predisposition in order to ensure minimal attenuation and reflections at their junction, particularly, in order to counter the effects of a thermal expansion of the ferrule or traction on the optical fibers. This maintenance is advantageously obtained by an extension of the "centerer" ferrule's with the aid of a tool, as described later. After the "centerer" is relaxed, it tends to naturally contract maintaining the two fibers in contact and under pressure on each other.

At each end of the ferrule, **connecting clamps** (3) that are linked together by the "centerer". Each of the connecting clamps is a closed state making the diameter of the ferrule's bore smaller than the diameter of the optical fibers to be connected.

Clamps may be prolongated by a section comprising a central bore with a diameter a little bit smaller that cladding diameter.

Thus, the clamps will restrain the cladded part of the fiber to avoid breaking or failure at the junction between cladded and uncladded fiber

A free length of uncladded fiber allows to adapt to concentricity default between outer diameter of cladding and uncladded fiber.

With respect to the present invention the connecting clamps have the function of firmly holding each of the two fibers in the ferrule in a way such that the contraction of the "centerer", once released by the tool, allows for the compression of one fiber against the other. In a preferred embodiment, end cones (4) are located at the extremites of the ferrule to allow for the deformation of the ferrule in advance of and to easily allow for the smooth insertion of the optical fibers. In a preferred embodiment, conic grooves (5) are located on each side of the "centerer" to facilitate its expansion by the tool. The connecting clamps have one or more longitudinal slots (6) that cut the ferrule, traversing radially outward from the centre. Each slot cuts the ferrule from one extremity, traversing the length of the

"centerer" and stopping at a point between the centre and the opposite extremity. Figure 1 shows an example realisation with four longitudinal slots, comprising two sets of two slots at 90°. Each set comprises two slots cutting the ferrule radially outward in opposite direction and the two slots cut the ferrule along the orthogonal axis. This illustration is not restrictive in terms of the number of slots. Cuts B to F visually illustrate the location of the slots along the length of the ferrule. With respect to the present invention, these slots operate to allow for sufficient deformation of the bore of the centre to easily and reproducibly insert the optical fiber while maintaining a reproducible bore that can be made using conventional industrial means and is minimally smaller than that of the optical fiber. In the case where a single slot is used, it could traverse the entire length of the ferrule.

The bore of the ferrule is protected by two caps (7), as shown in Figure 2, in order to prevent contamination by dust or any other any substances. These two caps have wire centres whose extremities are located at the "centerer" of the ferrule, to allow for optimal centring of optical fibers when replaced by them.

B. ***Use of the ferrule*:**

The ferrule will be used with a tool that can deform it in order to put the optical fibers in place.

Only the basic functions for operation when used with the tool are described. The figures are presented only as an example and are not intended to limit the scope of possible implementation of the tool. For example, grip pliers, automated and motorized tools, tools built in and around each ferrule, etc.

In one embodiment, this tool essentially comprises:

A pair of external grips that engage the ferrule at the two end cones

A pair of internal grips that engage the conic grooves of the "centerer" of the ferrule.

a) Deformation of the "centerer":

As illustrated, the ferrule in this embodiment is "dumbbell" shaped, the diameter of the connecting clamps greater than that of the centerer. The ferrule is placed on the two internal grips (8), which are engaged one from the other. Each of the internal grips comprises a cone (9) that engages each of the conic grooves (5) of the ferrule's "centerer" (see Figure 2). Tension is applied between the two grips to deform the "centerer". This deformation can be broken down into two phases: one consisting of the elongation of the "centerer" and another one consisting of the elongation of the bore's diameter making it larger than the diameter of the fibers to be connected.

The slots (6) that divide the "centerer" allow the advantageous combination of the expansion of the "centerer" with an increase in diameter of the bore through the reaction obtained by the two conic grooves of the "centerer".

In this way, the slot or slots in the "centerer" allow for the enlargement of the bore's diameter combined with the expansion of the "centerer".

b) Placement of the first fiber:

The two external grips (10) also comprise a cone (11) that is inserted in the entry of the connection clamps. The first external grip is brought close to the ferrule and its cone is inserted in the end cone. A force is applied between the external grip and the corresponding internal grip on the same side of the ferrule (see Figure 3). This force opens the connecting clamp by using the force obtained from the end cones. The opening of the connecting clamp is such that the bore diameter is larger than the diameter of the optical fibers. Once the first connecting clamp is opened, the cap is removed and replaced with the first optical fiber, which had been previously prepared. The fiber is abutted against the end of the second cap, which is still in place. In this way, the junction between the fibers is made at the middle of the ferrule ensuring the holding of the two fibers in place. Preparation of the fiber comprises removal of the fiber, cladding and cleaving the fiber.

The first external grip is then relaxed so that the first connecting clamp closes on the fiber and maintains it in place (see Figure 3).

c) Placement of the second fiber:

The second external grip is brought close to the heading to the ferrule and its cone is engaged with the end cone located on the ferrule. A force is applied between the external grip and the corresponding internal grip on the same side of the ferrule (see Figure 4). This force opens a second connecting clamp. The opening of the connecting clamp is such that the bore diameter is larger than the diameter of the optical fibers. After opening the second connecting clamp, the cap is removed and replaced with the second optical fiber, which had been previously prepared.

The second fiber is abutted against the end of the first fiber, which is already in place (see Figure 4). The second external grip is then relaxed so that the second connecting clamp closes on the fiber and maintains it in place (see Figure 4).

d) Closing of the Ferrule:

Although the "centerer" of the ferrule is still maintained in traction, the relaxation of both external grips results in a contraction in the diameter of the bore in the region of the "centerer" (see Figure 5). Thus, the "centerer" is applying a radial force on the two fibers leaving no "play" between the fibers and the ferrule. The two optical fibers are therefore perfectly centered with respect to each other.

Once the force applied, the internal grip is relaxed, and the "centerer" is no longer maintained in traction, its length tends to contract and its two fibers are abutted with each other. This compression allows for the contact of the two fiber ends to be maintained under the effect of traction of one of the two fibers or the effective thermo expansion of the ferrule. In the case of a drop in temperature, the ferrule will have a dimensional contraction greater than that of the fiber. This contraction would have a principal effect of increasing the contact pressure between the fibers and the pressure of the grips on the fibers. This

increase in pressure will be tempered by using the materials listed in paragraph A and will have no effect on the junction of the fibers and their quality of transmission and reflection. This remains true as long as the temperature of the ferrule remains higher than that of (M's). If the temperature of the ferrule is less than that of (M's), then the grips are relaxed and the fibers could slide within the ferrule with minimal effort and there is a reduction in contact pressure between the fibers. Thus, this case, there is a risk of degradation of transmission and reflection characteristics of the junction by separation of the fibers.

The tool may then be left in place if it is integrated with the ferrule, or if it is removed from the connection (see Figure 5).

C. Reuse of the ferrule:

The ferrule of the present invention may be removable. In order to do this, one may use the same deforming tool used to create the junction. In a particular embodiment, using the two internal grips, the "centerer" is "bent" to relax the contact pressure between the two fibers. Then, using the first external grip, the first connecting clamp is expanded to open the bore, thus making it possible to remove the first fiber. The cap is then reinserted into the bore, allowing it to abut with their second fiber. The same operation is repeated to the second connecting clamp, which expands the bore, thus making it possible to remove the second optical fiber and then the second cap is inserted. The second connecting clamp and the two internal grips are then relaxed, and the ferrule may then be reused to make another optical junction or connection.

It is to be understood that the various features of the present invention might be incorporated into other types of ferrule devices, and that other modifications or adaptations might occur to workers in the art and it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. All

such variations and modifications are intended to be included herein as being within the scope of the present invention as set forth. Further, in the claims herein, the corresponding structures, materials, arts and equivalents of all means or step-plus-function elements are intended to include any structure, material, or acts for performing the functions in combination with other elements as specifically claimed.